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THE RED ROT OF CONIFERS

by F. H. ABBOTT

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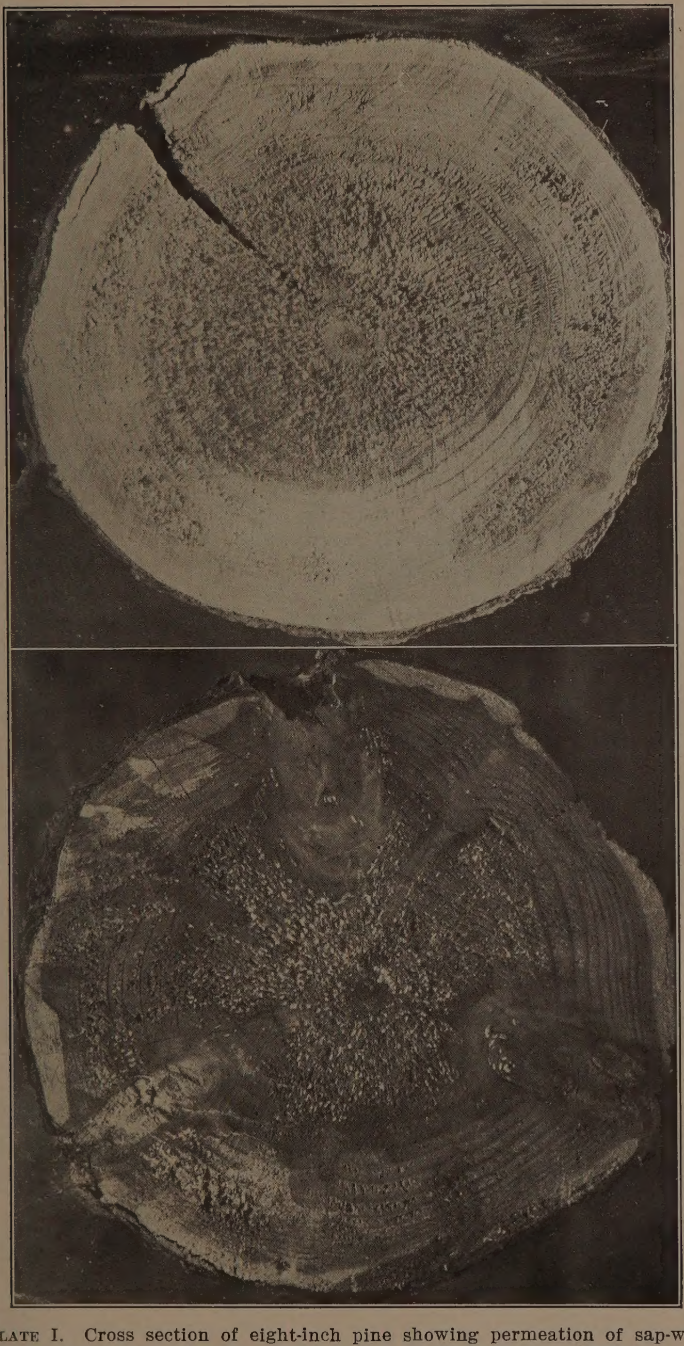

PLATE I. Cross section of eight-inch pine showing permeation of sap-wood by the fungus (upper). Cross section of diseased pine (lower).

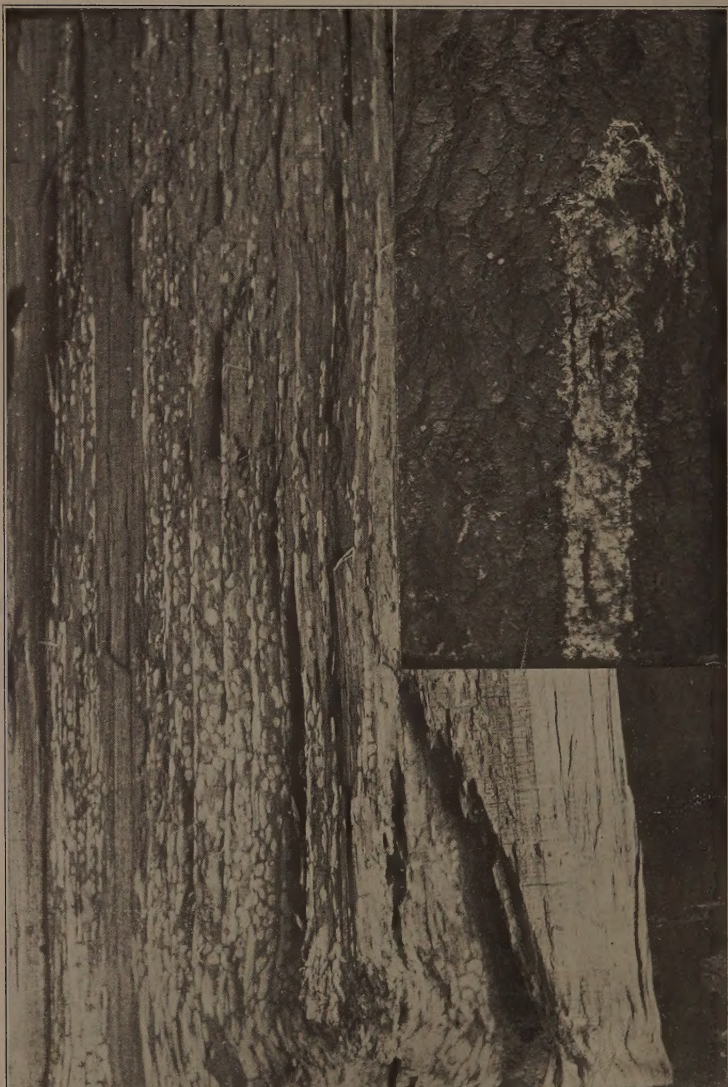

PLATE II. Longitudinal section of pine showing appearance of infected wood (main view). Fruiting body of *Trametes Pini* on a fourteen-inch pine, together with pitch exudate below fruiting body (in upper right hand corner).

BULLETIN 191: THE RED ROT OF CONIFERS

By F. H. Abbott[1]

SUMMARY

The so-called red rot of conifers is caused by the fungus *Trametes Pini,* which is primarily a parasite, assuming more or less the characters of a saprophyte when the tree falls. The fungus commonly attacks five species of conifers: tamarack, pine, hemlock, spruce and balsam. Its ravages are greatest in unthinned stands, especially pure stands of white pine.

Infection occurs mainly through broken branches which expose the heart-wood. Root infection is doubtful. Sporophores are the principal means of spreading the disease. They form on all host species but vary in form from an incrustation on the spruce and balsam to a bracket or hoof on pine and tamarack. They exist on both standing and falling trees. The mycelium spreads more rapidly up and down the trunk than across it. The damage to the wood is wrought by the solution of its lignin content by the enzym of the fungus. This damage appears to cease when the tree falls.

Laboratory cultures of the fungus from various sources exhibited uniformity. Spores were not produced in the cultures, at least up to six months. Successful cultures may be made on sterile wood.

Prevention is best effected by proper thinnings, removing diseased trees and destroying fruiting bodies.

The weight, breaking and crushing strengths of the woods were decreased approximately in proportion to the permeation of the wood by the fungus.

The red rot of conifers damages Vermont timber owners annually to the extent of about a quarter of a million dollars. The diseased wood is used in the manufacture of boxes, tubs, wooden pails, etc.

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[1] The writer expresses his appreciation of the assistance he has received from Arthur S. Graves of Yale University, B. A. Chandler of the Vermont Forestry Department and from the Station Forester and Plant Pathologist in assembling the data and in preparing this paper. The collection of references was facilitated through the assistance of Perley Spaulding of the United States Department of Agriculture. Valuable specimens were contributed and field observations made by Mr. Chandler. The collection of the data regarding losses in the mills and woods was accomplished only through the cordial cooperation of landowners, millowners and operators. C. G. Hedgecock of the United States Department of Agriculture also assisted in the identification of sporophores and diseased wood.

I. Financial Losses

According to the 1910 census report, reviewed by the United States Forest Service in Vermont Forestry Publication No. 11, "Wood Using Industries of Vermont," Vermont produces lumber, lath and shingles from pine, spruce, hemlock, tamarack and fir, totaling 194,273,000 board feet. Were this all sound timber, free from red rot and other defects, it would average at the mill $20 per thousand square edged. As a result of the writer's inspection of lumber in twenty mills and yards in various parts of Vermont in the spring of 1913, it is estimated that on account of the red rot nine percent of this total is reduced to a grade worth approximately $10 per thousand. In other words, on a total of 17,484,570 board feet of timber affected by red rot, there is an annual loss of $174,845.

But this is not all. These figures are taken at the mills and shipping points and do not represent the lumber before it is marketed. Much of the timber—calculated, from observation in the woods and estimates by lumbermen, at 2 percent of the actual cut in the woods—is so badly diseased with red rot as to be entirely useless. This, of course, never is hauled from the stump. Basing the calculation on the census figures and for the total output, this absolute loss of 2 percent totals 3,885,460 board feet. Sound logs to this amount would be worth in the woods approximately $25,000. In addition to these losses there is the great loss to trees which become diseased and are dying constantly in the forests, eventually falling to the ground and rotting. The total annual loss to Vermont timber owners due to the red rot disease, therefore, may be placed approximately at a quarter of a million dollars.

The percentages used in this calculation were averages taken from data collected in person by the writer from actual mill tallies, observations and quarter-acre circle tallies made in the woods, and from figures and estimates furnished by mill owners and operators throughout northern Vermont.

Investigations made by the writer indicate that in white pine lots there was a loss of 8 percent of value due to the disease; in pure spruce 3.5 percent; and in mixed conifers, 5 percent.

II. External Evidences

To the lumberman or wood-chopper the evidence of the presence of red rot in a standing tree in the forest is unmistakable. If a glance

at its general appearance does not tell him, he sounds the tree with his axe to see if it is worth felling. To the untrained person, however, considerable observation is necessary to judge with any degree of accuracy whether a tree is or is not diseased. Of course the discovery of a fruiting body (Plate III) is a sure indication, but aside from this evidence one can judge only from general appearance. Perhaps the most reliable indication, at least in the pine and spruce, is the abnormal exudation of pitch or resin from old knot-holes, or, if the disease has progressed far enough, from other points on the bark. This pitch drops down the sides of the tree and is very noticeable, as is shown in Plate II, upper left hand corner. If the fungus has invaded the trunk of the tree sufficiently to affect its health seriously, a general paleness of the bark and even of the foliage ensues. These evidences are not confined to any particular part of the trunk. The very first stages of the disease are betrayed by this pitch exudate. Suspected trees manifesting these early evidences of the malady were cut, which, upon internal examination, revealed only the red color of the heartwood, which is the result of the first structural change brought about by the fungus. Later in the progress of the disease all the external evidences become intensified so that advanced stages are detected more easily.

III. SPECIES AND CONDITION OF TYPES ATTACKED

Susceptibility of species. Red rot is found commonly in the five soft wood species: pine, spruce, hemlock, balsam and tamarack. Von Schrenk (2) states that "of the five trees the tamarack seems to be the most readily attacked, the spruces come next and the balsam fir last." Although tamarack is not as plentiful in Vermont as the other species, the writer's observations tend to confirm Von Schrenk's statement as to its susceptibility. In regard to other species, however, the writer's study of his data leads him to conclude that, in Vermont at least, white pine is second in susceptibility, while spruce, hemlock and balsam are susceptible to invasion in about the same degree. It was noted that spruce in mixed stands appeared more prone to attack than when growing in a pure spruce stand. This is not easy to explain, unless it may be due possibly to better self-pruning and to more healthy and favorable silvicultural conditions.

Pure white pine stands showed greater amounts of red rot than did any other type. Where the disease was present at all in the white

pine, it seemed to be distributed much more uniformly than in the mixed stands.

Silvicultural conditions. Certain silvicultural conditions appeared to favor the presence and spread of the disease. It was predominant especially in tracts which were in need of thinning. A notable case of this sort was found in Orange County where the trees ranged from 6 to 14 inches in diameter at breast height and were growing so closely together that the wind had broken many branches. The heavy mass of crowns did not allow the entrance of sunlight, which is an important factor in the healthy growth of a forest.

Topography. So far as could be determined, the effect of topography upon the presence of the fungus seems very slight. The reports of lumbermen on this point were variable and evidently were governed by local conditions. Comparison of the opinions of lumbermen in different localities, strengthened by the writer's observations in the woods, leads to the conclusion that red rot lumber is as common on high rocky land as in the swamps and lowlands, with the exception of tamarack which, of course, occurs only in lowlands.

Wind. It is believed that the wind is a more important factor than topography. Areas exposed to heavy winds show more red rot decay than do sheltered stands. This condition might be explained by the fact that the damage done by the wind in breaking branches leaves open places or branch wounds where the fungus may enter the tree. The wind also aids in carrying spores from one tree to another.

Age. Previous writers have ascribed much importance to the supposed fact that only the oldest trees in the stand are affected. While this may be true in some sections, many specimens of trees not more than 25 or 30 years old were found by the writer to be infected. Von Schrenk's statement that the fungus attacks living trees only after they have reached the age at which they form heart-wood, probably is a more correct conception of the matter.

IV. Distribution

Numerous German references report the occurrence of this fungus in all parts of that country where any considerable stands of coniferous trees are found. Möller (5) says "It is present wherever the conifers grow in any abundance and the damage caused by it reaches into the millions of dollars annually." Hartig (1) states that it is very abundant in the pine woods of North Germany and occurs also, but less

frequently, in the spruce woods of South Germany. That it affects the conifers in other eastern countries is evidenced by the report of Khan (6) on its occurrence in India in 1904.

Von Schrenk (2) has reported in a general way on its occurrence in Maine and other New England states on white pine, red spruce, white spruce, hemlock and tamarack. The parasite attacks living trees after they have reached the age at which they form heart-wood, and honeycombs the wood in such a way that it appears to be filled with small holes, many of which seem to have a slimy white lining.

The writer has tried to secure information which would afford accurate data concerning its occurrence in Vermont, by the collection of statistics from different parts of the State. The percentages of disease in spruce and mixed stands appear to be fairly uniform in all places where data were obtained. With the exception of a few local situations, either badly infected or entirely free from disease, one may expect to find in most cuttings losses varying from 3 to 5 percent.

The presence of the disease, however, was not as uniform in pine trees as in the others mentioned. Many small tracts, especially isolated ones, were found where no disease was apparent. On the other hand other places were found where many trees were affected and the loss was very large.

With the exception of the Passumpsic valley, which appears to be excellent pine land, and where very little red rot was found, the distribution of the disease is irregular. Along the shore of Lake Champlain, tracts less than ten miles apart were located where both extremes of conditions were found. The Connecticut valley shows a similar condition.

It is the writer's opinion that the best pine lands show the greatest freedom from disease because the more rapid and uniform growth results in better self-pruning and healthier general conditions.

V. THE FUNGUS

Name. The fungus causing the red rot of conifers is one of the Basidiomycetes, *Trametes Pini.* It is a parasite of growing coniferous trees and assumes the characters of a saprophyte, (that is to say, a fungus living upon a dead plant or animal) to a greater or less extent upon the death of the tree, so long as the moisture and food contents of the host remain favorable to its development. The question of its adaptability to a saprophytic mode of life is one of much economic im-

portance from the point of view of its ability to continue the formation of fruiting bodies on fallen trees and thus greatly to increase the spread of the disease.

Growth of mycelium. Von Schrenk (2) states that destruction of the wood, at least, ceases upon the fall of the tree, but that whether the fruiting bodies on fallen trees do or do not function to any great extent remains an open question. That the growth of the mycelium (the thread-like tubes which penetrate the wood and nourish the fungus, tubes which in their function are analogous in a way to the roots of higher plants) in fallen trees is dependent almost entirely upon moisture conditions, was proved conclusively by the writer by taking uniform slabs of diseased pine, placing them in various conditions of moisture and watching the progress of the growth of the mycelium and the destruction of the wood. Slabs placed under cover where conditions are such as are found ordinarily where lumber is seasoned, showed no further growth of the fungus. The wood dried out and its pithy appearance assumed a more open character. On the other hand, slabs of the diseased wood left in contact with the ground, or near moisture, showed abundant growth of the mycelium, which extended even to the surface of the wood. Whether infected wood left in such conditions ultimately would or would not form functioning fruiting bodies, is undetermined. However, it is believed that trees which fall in the woods as a result of permeation by the fungus do not fall ordinarily under such conditions as tend to favor the continued growth of the mycelium. The trunk of the tree is more likely to be attacked by fungi such as *Lenzites sepiaria* and other saprophytes that can live in a drier situation.

Method of attack. Any tree wound which opens up a way to exposed heart-wood enables the red rot fungus to germinate and the mycelium to penetrate the wood. Once the mycelia have gained entrance, they spread rapidly, both up and down the trunk, along the tracheids (i. e. wood cells used simply as water carriers) longitudinally, and more slowly across radially.

Resistance. Apparently the only resistance offered by the tree takes the form of a free exudation of pitch. In the younger trees this discharge is sufficiently large to hinder the progress of the mycelium while the lessened amount of pitch which is exuded by the older trees accounts for the increased destruction.

It is stated by Von Schrenk (2) that the mycelium of *Trametes Pini* flourishes in both the heart-wood and sap-wood of spruce, hem-

lock, fir and larch, while in pine it grows only in the heart-wood. That the latter is not always true is shown in Plate I of a cross section of an eight-inch pine, in which it will be noticed that the destruction has continued irregularly into the sap-wood. This specimen was taken from a standing tree upon which a fruiting body was found.

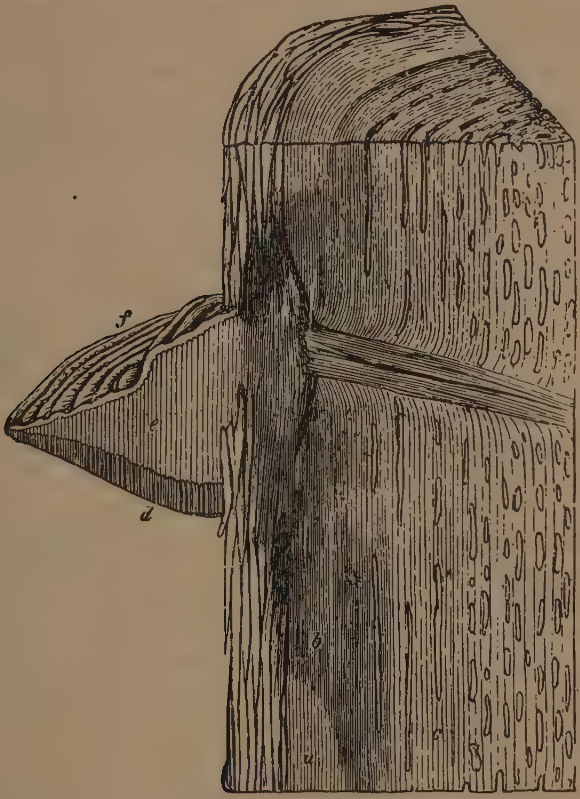

Figure 1. Part of stem of a pine bearing sporophore of *Trametis Pini* (one half natural size) (After Hartig).

Hartig (1) says the fungus cannot enter through old branches naturally pruned. This point was investigated and it was found that the tree forms a natural protection for itself. When the branch dies the free exudation of pitch causes that part which lies adjacent to the cambium, (the growing tissue just inside the bark), as well as that inside the tree to become hardened and impenetrable. This con-

dition is shown clearly in Figure 1, which is a longitudinal section of a diseased pine, cut squarely through the center of the knot. It will be noticed that the fungous growth is present in the vicinity but does not penetrate this resinous wood of the old branch.

Morphological characters; wood dissolution. The visible effects of the growth of the fungus in the wood are described by Von Schrenk (2) for spruce in part as follows: "The first effect to be noticed is a change in the color of the wood from natural light straw color to a purplish gray. Very soon this gray deepens to a red brown. Black lines precede the appearance of small white areas. These areas usually are some distance from each other and are arranged longitudinally (Plate II). Some of the holes fill with a mass of white fibers. As the holes grow in number and size they appear to unite longitudinally rather than radially. As the disease advances in the tree, the destroyed cells fill with a dark brown mass of hyphae[1]. These hyphal plugs occur in nearly every tracheid and are accompanied by a brown incrustation which dissolves in part in dilute potassium hydroxid and entirely in warm nitric acid. These incrusting substances apparently were decomposition products and were laid down in liquid form.

"The changes in the cell walls resulting from the attack of the mycelium are fully described by Hartig (1). There is a gradual extraction of those elements which give a lignin[2] reaction due to the probable secretion by the fungus of lignin-dissolving enzyms.[3] This begins in the tertiary lamella and proceeds outward slowly through the secondary lamellae. The primary lamella splits at this state and dissolves, leaving the individual tracheids entirely free from each other and composed approximately of pure cellulose. The white spots are the points at which the change to cellulose has taken place. Preceding the change of the wood fiber to cellulose, the wood is filled with masses of hyphae which become masses in centers and bring about the dissolution of the wood.

"The hyphae grow out from the original centers in all directions, proceeding faster up or down the stem parallel to the tracheids than they do across them. It is the opinion of the writer that the decomposition products cause the destruction of the wood to stop at this point. In the newly invaded trunks the mycelium is colorless. The hyphae are somewhat thick walled and have numerous short branches which penetrate the walls in all directions."

[1] The term "hyphae" as used here, is synonymous with mycelia.
[2] The woody substance of the cell wall.
[3] An enzym is a ferment possessing the power to decompose organic compounds.

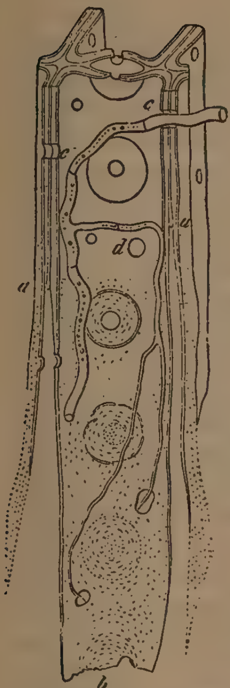

Figure 2. A tracheid of *Pinis sylvestris* which has been decomposed by *Trametes Pini*. The primary cell-wall has been completely dissolved as far as aa. In the lower portion of the figure the secondary and tertiary walls consist of cellulose alone, in which granules of lime are distinctly recognizable, b; filaments penetrate the walls and leave holes behind, d. e.
(After Hartig).

Figure 2, copied from Hartig, shows more clearly than can be explained the appearance of the mycelium in the tracheids and the gradual solution of the lignin brought about by the enzym of the fungus.

VI. Cultural Studies

Specimens of diseased wood were secured from several sections of the State, though mostly from forests near Burlington, in August, 1912, the trees being in various stages of decay. These specimens were examined microscopically and the fungus was grown on lima bean agar (Clinton's formula) and a synthetic agar composed of peptone and the necessary salts, which was strongly acid in its reaction.

Inoculation methods. Some samples for inoculation were taken from standing trees on which fruiting bodies had developed, others from logs or sawed lumber in lumber yards, and in two cases successful cultures were made from particles of wood taken from a knot-hole in a suspected pine upon which no fruiting body could be found. The mycelia obtained from all these sources showed noticeable uniformity in their growth or media. Particles of fruiting bodies also were used for inoculations and, in comparison with each other and the cultures made directly from wood, gave equally uniform results.

Most of the inoculations were made directly from the specimens of wood. By carefully handling the specimens with sterile forceps and cutting away the external portions of the wood with a sterile knife, small particles of the diseased wood fiber were obtained, which, when introduced upon the surface of the tubed media, gave about 90 percent of pure cultures.

Mycelial growth. At first the mycelium made slow growth, from

ten days to two weeks being required before visible growth could be detected in the tubes. Plate IV shows a photograph of a six-weeks-old culture on lima bean agar. During the first stages of the growth the hyphae, (that is to say, the filaments of the fungus), were pure white in color. They spread over the entire upper surface of the media, forming a mat about one-sixteenth of an inch in thickness. In no case did they penetrate the media to any extent.

Inoculations were made upon media in deep petri-dishes, about 2.5 inches deep and 3.5 inches in diameter, in order to promote a longer period of mycelial growth before the media began to dry. The growth in the petri-dishes was not essentially different from that in the tubes.

In all cases the mycelium retained its white color for a period of from six to eight weeks, then slowly turned to a brown which grew steadily darker for about eight weeks, after which time there seemed to be little increase in amount of mycelium and no change in color. The brown color exhibited so uniformly by the culture apparently is due to a sort of incrustation which is laid down about the mass of mycelium. The fact that this incrustation is soluble in part in potassium hydroxid and entirely in warm nitric acid indicates, as Von Schrenk (2) has stated, that it is due to the presence of decomposition products. This coloring matter diffused through and stained brown the lima bean agar after two months. The growths on the two kinds of media differed only in minor particulars.

Sterile wood cultures. In order more closely to follow the fungus in its attack upon wood, cultures were made in the following manner: Small blocks were sawed from each of seven different kinds of healthy wood, spruce, pine, hemlock, tamarack, balsam, birch and oak. These blocks were taken from the trunks or branches and sawed in such a manner that both heart-wood and sap-wood were present in each block. They then were put into an ordinary test tube, in the bottom of which had been placed previously a small ball of water-soaked cotton. The tubes then were plugged and sterilized. Inoculation was accomplished by introducing small particles of mycelium from previous media cultures. Growth in the dark and at room temperature started on the wood almost immediately and spread irregularly over the entire surface of the block. Eight inoculations, besides a check, were made on each kind of wood and in 95 percent of the tubes the cultures appeared pure. The fungus apparently showed no preference for the sap-wood.

Growth on different species. Comparison of the amount of hyphae

in the tubes showed that the susceptibility of the wood seemed to range in order as follows: Tamarack, pine, hemlock, spruce, balsam. This order of susceptibility is the same practically as that noted by Von Schrenk (2) in New England forests.

The inoculations made on oak and birch were successful, the fungus growing luxuriously; but the damage to the wood was done more slowly and its extent relatively was very limited. The attack of the fungus on the hard woods should be studied more thoroughly. The preliminary sterilization, of course, may have rendered them soft and also may have brought about chemical changes which rendered them more readily open to attack than when in their natural state.

The brown incrustation occurred fully four weeks later in the case of all eight cultures of the tamarack and balsam than in the cultures on pine, spruce, and hemlock inoculated at the same time. Microscopical examination revealed no essential difference in the fungus as cultivated on the different woods, except that the hyphae cells possibly were a little larger in diameter on the tamarack and smaller on the hard woods.

Influence of moisture. The growth of the fungus is profoundly affected by the presence or absence of water in the tubes. Without exception whenever moisture was lacking to any great extent, the growth of the fungus was affected directly. If water was omitted at the time of inoculation, the culture failed to develop. If the fungus grew luxuriantly in the presence of moisture it ceased its growth immediately and dried up if the water supply was withdrawn. Tubes in which this drying out process had taken place once, but slowly reestablished growth upon the addition of water.

Spores. The cultures were examined microscopically at various stages for spores. The last of these examinations was made in May, 1913, and, even on cultures which had been growing since September, 1912, no trace of such reproduction could be found. The marked uniformity of the general characters of the mycelium, noticed in all the slides prepared from the different cultures, indicated that the same fungus had been isolated in all cases. The growth of the fungus on the sterilized wood cultures produced the same appearance as that taken from a diseased tree in the forest. Blocks of wood are shown in Plate IV on which the fungus had flourished for a period of six months but from which the mycelium was scraped from the wood to show more clearly the presence of the white-lined pockets which are so characteristic of the disease.

VII. EFFECT OF THE FUNGUS ON THE WOOD

The change from the natural color of the wood to a red brown has been responsible for the name of "red rot" lumber, by which woodsmen and lumbermen designate the diseased wood.

Breaking and crushing strength tests. In order to show the extent to which the changes wrought by the fungus as outlined on pages 7 to 10 take place, and to afford a comparison of diseased and healthy wood from the standpoint of the use of lumber for manufacturing purposes, tests of breaking and crushing strengths were carried out as follows: A complete section of a diseased pine log about 12 inches long was taken from a standing tree in Bradford. This tree was about eight inches in diameter and about 35 feet high. A fruiting body was found at a knot-hole four and one-half feet from the ground. A cross sectional photograph (Plate I) indicates the extent to which the fungus had penetrated the wood. This 12-inch section was seasoned in a boiler-room where it was subjected approximately to the heat employed in an ordinary kiln-drying process. The log then was sawed as economically as possible into sticks with an average measurement of 1.1 x 1.2 x 10 inches. These sticks were assorted then into three classes, according to the extent to which the fungus was present in each, as follows:

(1) Showing very little or no evidence of disease.
(2) Fungus growth on one or two sides.
(3) Thoroughly ramified by the fungus.

The weight of each stick and its volume by displacement of water were obtained. Breaking strengths were determined on sticks ten inches long and crushing strengths were determined on five-inch lengths.[1]
Four sets of tests were conducted for each class. A summation of results follows:

SUMMARY OF TESTS FOR THE THREE CLASSES

Class	Volume c.c.	Weight grams	Diameter inches	Pounds to break	Pounds to crush
Free from disease	240	89	1.1 x 1.2 x 10	610	6620
Partial infestation	247	78	1.1 x 1.2 x 10	498	3910
Complete infestation	248	67	1.1 x 1.2 x 10	337	2440

This table is self explanatory. It shows plainly the relative decrease in weight and in breaking and crushing strengths proportional to the extent to which the fungus had penetrated.

[1] The strength tests were carried out in the College of Engineering under the direction of J. O. Draffin of the Class of 1913.

Clearly the fungus is capable of destroying the wood and makes it unfit for manufacturing purposes. The advisability of cutting and marketing trees affected by the disease as soon as the presence of the fungus is noted, is evident. In this way only can the timber be used at all. It should be noted that the strength of the sticks cut from disease-free wood corresponds closely to that of standard seasoned pine. This tree, as a whole, however, was affected so seriously with disease that at least 50 percent of it would have fallen into a $10 grade, and 25 percent of it was utterly useless.

VIII. Method by Which the Fungus Spreads Through a Forest

Root infection. According to Khan (6) an examination of various specimens of the roots of coniferous trees in an East Indian forest infected with *Trametes Pini* showed that there is a strong possibility that the disease may spread by the passing of the mycelium from the roots of diseased to those of healthy trees. Even more striking is Runnebaum's (4) statement based on the inspection of 70 infected trees, to the effect that 50 of them had been infected from the roots. A careful examination of the roots and trunks of these 50 trees, on the side on which the fruiting bodies occurred, showed mycelium up to a point only half a meter higher than the level of the ground. The infection in the other 20 trees evidently had occurred in a branch wound, because the rot was confined to the parts above ground. While this channel of infection may be open to some cases, the chances of the fungus penetrating the cambium and sap-wood of an uninjured root seem rather slight. In any case the fungus can be spread thus but slowly. The writer is of the opinion that root infection does not take place to any great extent in this locality, certainly very few of the specimens seen in Vermont were diseased below the ground. It may be that the fungus has been confused with its closely allied form, *Trametes radiciperda,* which produces much the same condition of decay in the wood but is spread solely by underground methods, its fruiting bodies forming below the surface. Tubeuf (3) has made clear the distinction between *Trametes Pini* and *Trametes radiciperda,* although the two species produce much the same condition in the wood.

Fruiting bodies or sporophores. The fungus follows in general the habits of other wood fungi and spreads through a forest mainly by the production of spores in a fruiting body, or sporophore. That these sporophores are very plentiful on the diseased trees in German forests

is indicated by the constant reference made to their occurrence by German writers. Von Schrenk (2) speaks of them as being "extremely common on all (New England) affected trees." Specimens have been collected from forests in Maine, New Hampshire, Vermont, New York, Ontario, Quebec and New Brunswick. However, the writer did not find these fruiting bodies as common, at least in Vermont, as they have been represented to be. No trace could be found on a large proportion of the infected trees, the only external sign of the disease being an abnormal exudation of pitch from knot-holes and a general pale and unhealthy condition of the foliage. However, the sporophores were found occasionally on every diseased tract.

The sporophore of *Trametes Pini* is easily distinguished from allied forms by the light red-brown color of the hymenial or fruit-bearing surface and by the regular small round pores. The pores on the specimens obtained in Vermont seem smaller than those occurring on specimens from other sections. The form of the pileus or cap varies with the species of the host plant. Hartig (1) ascribes this difference to the various amounts of resin contained in the trees of the several species. The sporophore on the pine appears characteristically in the form of a large bracket, situated on the surface of the tree where an old branch stub has broken off. Plate III shows this characteristic appearance. An exudation of pitch almost always accompanies the presence of the fruiting body. Plate III shows two specimens of fruiting bodies or sporophores collected, respectively, at Bradford and Burlington. In the case of the spruce, tamarack and fir, these characters do not hold. The form of the sporophore varies from that of an incrustation to that of a bracket, and it does not confine its location to the nodes but may develop at any point.

These sporophores give rise to the spores which are carried about by the wind until they find a suitable place for germination. Where old branches have been broken off, exposing the heart-wood before complete protection to the wound has been effected by the resinous deposit in the branch stub, the spore finds the most favorable conditions for entrance and germination. Its progress in the heart-wood is rapid, but when it reaches the resinous sap-wood its advance is slower. About this time the sporophores begin to form. Where the dead branches have been broken off close to the trunk, the hyphae grow out from the stub and form a cushion. Von Schrenk (2) has explained carefully in detail the progress of the growth of the sporophore on pine, spruce and tamarack. The cushion formed on the branch stub is very small at

first and has the appearance of being covered with velvet. The radial growth of the hyphae is rapid and a sheet is formed which adjusts itself to the shape of the stub. At the edges this sheet projects from the bark and forms an irregular shelf, the top of which after a time becomes brown and hairy and ultimately develops into a bracket formation. The growth seems to take place most rapidly through the latter part of the summer and the early fall. The hyphae at the edge of the sheet extend their area, while those forming the walls of the pores grow vertically downward. It is not known to what age one of these sporophores may attain.

Most writers call attention to the fact that fruiting bodies are common only on the larger and older trees. While this is true to a certain degree, the production of sporophores by no means is confined to such trees. The writer found that they were as common on diseased trees less than seven inches in diameter as they were on larger and older trees. One good specimen was found on a pine about six inches in diameter and only about 30 years old. The entire surrounding stand in this case was only from 45 to 50 years old and fully as large a percentage of diseased trees was detected here as in any stand examined.

These fruiting organs exist on both standing and fallen trees. Von Schrenk says: "They were found on trees which had been cut down four years before and new ones were constantly appearing." In view of the fact that the mycelium practically ceases growth as soon as the wood is placed in a position where desiccation will take place, it would seem that such sporophores could not be kept in a condition to function for any length of time after the fall of the tree, unless the tree fell in a position to cause the excessive absorption of moisture. However, it is this faculty of fruiting to a greater or less extent on dead trees which must enable this fungus to accomplish its rapid spread.

IX. Preventive Measures

The discovery of this disease and of its method of spread in Germany immediately led to search for some means by which its ravages could be controlled. Most students of this malady as it occurs in Europe have suggested the following procedure:

1. *Prevention of branch breaking.* Laws have been enacted to prevent wood gatherers from breaking off branches which leave an open wound in the heart-wood, thus encouraging the entrance of the fungus. These wood gatherers damage forests which lie near cities and villages. They are supposed to take only the dry dead branches,

but in so doing often remove branches which still are partly green and in which the protective layer of resinous wood has not formed.

2. *Removal of fruiting bodies.* If fruiting bodies are removed and destroyed and a disinfectant is applied to their former sites on the trees much good will be accomplished. This may be done according to Möller (5) by a crew of two or three men equipped with ladders with instruments for hewing out the sporophores and with some form of disinfectant to apply to the spots where the fruiting bodies were located. Caterpillar tar (Raupenleim) is the disinfectant commonly used in this work. Its application in this manner is known to have prevented the formation of new fruiting bodies in at least 80 percent of the cases where it was used. Kienitz (8) states that it costs about 10 cents an acre to do this work.

3. *The cleaning out of infected trees.* Infected trees can be recovered thoroughly only by a careful survey of the tracts by a man who is trained in detecting the disease. The complete removal of the whole tree is necessary because of the chances of further infection, either from the mycelium or from fruiting bodies on the fallen trees. This operation should not be expensive, as enough of the lumber cut would be worth saving to pay for the cutting. This cutting could be made best in the form of a thinning. Hollrung (7) advises a complete inspection and cleaning of an infected forest every five years in order to maintain complete control of the disease.

Obviously all these methods are radical and are applicable in their entirety only where intensive forestry can be practiced. The problem of prevention in this country assumes a different aspect because lumber prices do not permit as intensive methods as obtain in Europe and because the sporophores apparently do not grow as abundantly, in the Northern states at least, as they do in Germany.

In view of the fact that evidence points toward the probability that fruiting bodies may form and function on dead trees, it appears that the first procedure should be to remove carefully all dead and diseased wood so that it will not spread the disease. Then, secondly, overthick plantations should be thinned.

The writer noted a significant fact in his study of Vermont forest conditions in their relation to red rot, namely, that the disease was much more prevalent in stands in need of thinning and of an improvement of silvicultural conditions than in well-handled stands. Proper thinnings should be made, if possible, in rotation. Thinnings thus

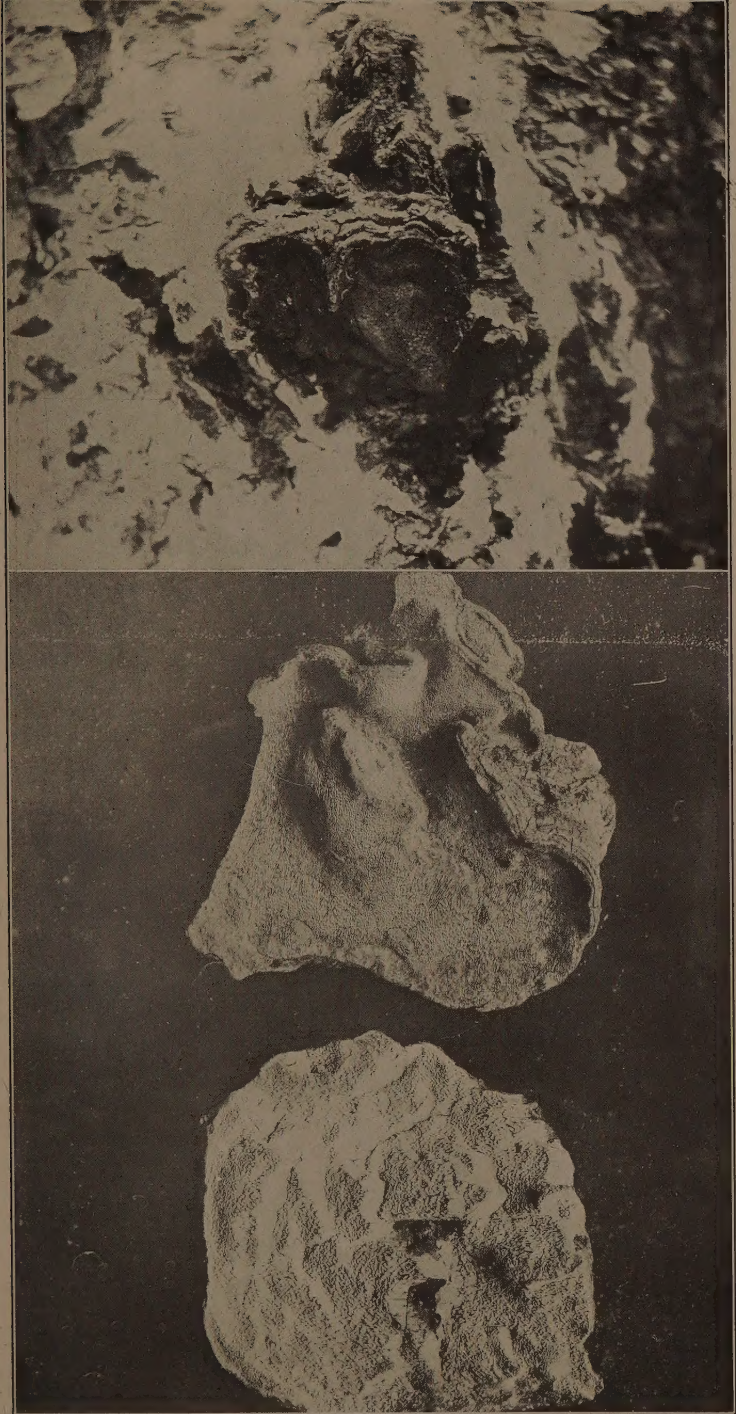

Plate III. Sporophore of *Trametes Pini* on pine; very nearly actual size (upper). Sporophores of *Trametes Pini* showing characteristic fine pores (lower).

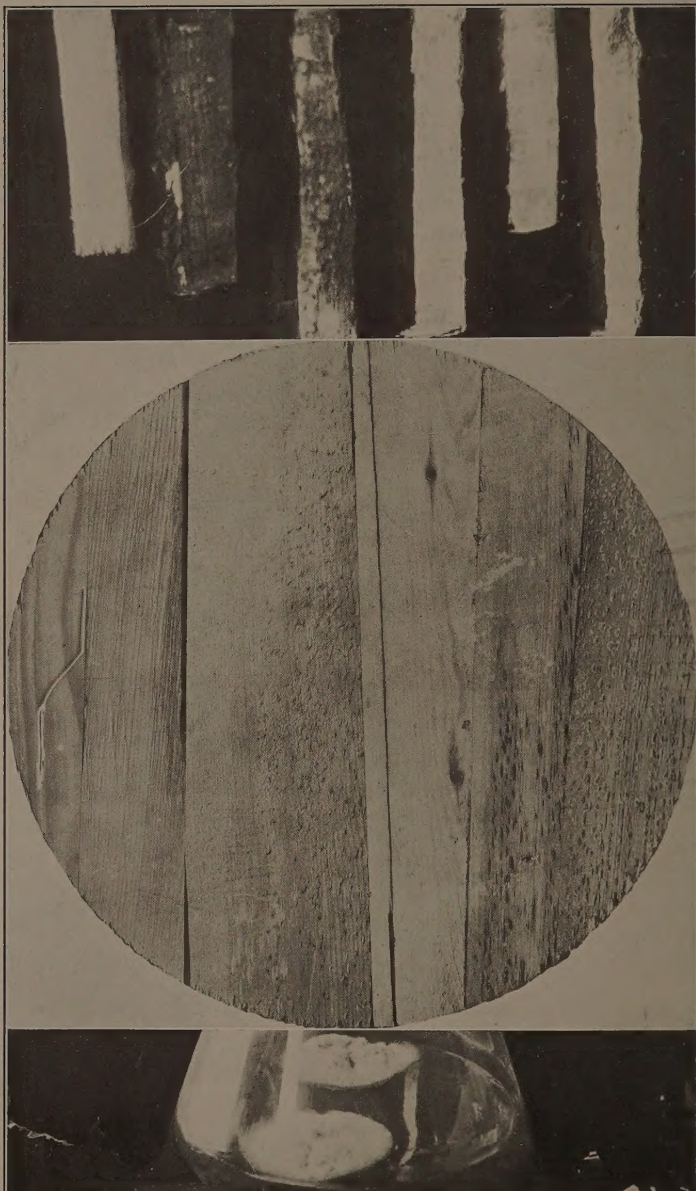

PLATE IV. Wood chips upon which *Trametes Pini* had flourished for six months. Mycelium is scraped from outside to give clearer view. From left to right: check, pine, tamarack, hemlock, spruce, balsam (upper). Butter tub cover; showing how infected wood is utilized (middle). *Trametes Pini* growing in cultures (lower).

periodically made at intervals not more than 20 years apart, should provide easily for the removal of all diseased trees. In the University forest at Burlington, where such thinnings have been carried out, a much better distribution of the trees has been effected.

The present method employed in many forests of cutting to a diameter limit, is inadvisable, because it leaves trees which may be diseased, or which may spread the disease, or trees which on the whole are undesirable from the point of view of reproduction or future lumber production. Experienced markers should be employed who understand the importance of such matters and who would be faithful in attending to the general betterment of silvicultural conditions.

Some lumbermen who have become interested in forestry have thought that they could secure reproduction of spruce by leaving trees diseased with red rot for seed purposes, thereby avoiding the financial loss incurred by leaving sound trees. Such procedure is dangerous because it tends to perpetuate the disease, not through the seed of the old trees, but by the fungus upon them.

It would be impracticable under existing American forestry conditions to attempt such operations as making a complete survey to remove and disinfect fruiting bodies, unless it were in some valuable grove where expense was not a factor.

X. Uses of Diseased Wood

During the writer's studies of the red rot situation in Vermont lumber yards and mills, certain interesting points were noted as to the methods employed in making use of the diseased wood, as well as to the extent to which the fungus could destroy the wood without totally impairing its value for manufacturing purposes.

Red rot lumber, as is indicated in previous pages, is considered worth about $10 per thousand. It is defined usually as "box-board grade." Some manufacturers are able to use it in such ways that they can afford to pay as much as $18 for it. Such lumber often is reserved by dealers for local trade. As a rule it does not pay to ship it.

The lumber graded as mentioned above, box-board grade, finds its principal use in the manufacture of boxes of all descriptions. It is not used alone but is mixed with a better grade in order to furnish a marketable product. It is used also in making pails, tubs, kegs, etc. Perhaps this is a more effective method of making use of this wood than that just cited, since much poorer lumber can be used by virtue of the

fact that a filler can be employed on the most decayed places and then the whole covered with paint to make an apparently perfect product. The photograph of a butter tub cover in the rough (Plate IV) shows the grade of lumber that can be used and also shows the proportion which can be introduced and still permit the structure to hold together.

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